Animal Science Publications | Animal Science

2-2012

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22

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1. Introduction

Consumer perception of processed meat products is a critical issue for the meat industry. In recent years consumers are increasingly conscious about healthy diet. However, most of the processed meat products contain high amounts of fat, which are related to chronic diseases such as obesity and cardiovascular heart diseases. Health organizations have suggested to reduce the intake of total dietary fat, particularly saturated fatty acids and cholesterol, as a mean to prevent cardiovascular heart diseases (NCEP, 1988). Consumers now want low or reduced-animal fat products with high palatability and nutritional quality (Pietrasik & Duda, 2000).

Animal fat is a major factor that determines the eating quality of meat products including texture, flavor and mouth-feel (Keeton, 1994). Therefore, reducing fat levels in meat products is not as simple as using less amounts of fat in the formulation. Twenty percent or higher reduction of fat content in meat products can lead to an unacceptable product texture, flavor and appearance (Miles, 1996). Total substitution of fat with water produces unacceptably soft and rubbery product with an increased moisture loss during processing (Claus & Hunt, 1991).

The problems caused by fat reduction in processed meat products can be minimized by replacing animal fat with fat replacers (Colmenero, 1996). Several studies have demonstrated that replacing animal fat with soy products or carbohydrate is successful in textural and sensory properties of low-fat products (Decker et al., 1986; Berry & Wergin, 1993; Yusof & Babji, 1996). Isolated soy proteins (ISP) were successfully incorporated into meat products to reduce fat, improve yields, and enhance emulsion stability. Carageenan increases yield, consistency, sliceability, and cohesiveness, while decreasing purge in low-fat products (Foegeding & Ramsey, 1986; Xiong et al., 1999; Lin & Mei, 2000). Maltodextrin, which is a hydrolysis by-product of starch, is widely used in foods as a funcitonal biopolymer that provides desirable texture, stability, appearance, and flavor (Wang & Wang, 2000).

Olive oil is a vegetable oil with the highest level of monounsaturated fatty acids (MUFA) and has attracted attention as a replcacer for animal fat in processed meat products. Olive oil has a high biological value due to a favorable mix of predominantly MUFA and naturally occurring antioxidants including vitamin E, vitamin K, carotenoids and polyphenols such as hydroxytyrosol, tyrosol and oleuropein. Oleic acid makes up 92% of the MUFA in foods, and 60-80% of the oleic acid comes from olive oil (Pérez-Jiménez et al., 2007). Olive oil contains 56-87% monosaturated, 8-25% saturated and 3.6-21.5% polyunsaturated fatty acids (IOOC, 1984). The potential health benefits of olive oil include an improvement in lipoprotein profile, blood pressure, glucose metabolism and antithrombotic profile. It is also believed that olive oil has a positive influence in reducing inflammation and oxidative stress. Thus, intake of MUFA may protect against age-related cognitive decline and Alzheimer's disease. Olive oil is also reported to help prevent breast and colon cancer (Pérez-Jiménez et al., 2007, Waterman & Lockwood, 2007).

This chapter discusses the effect of olive oil on the quality of emulsion-type sausage (Moon et al., 2008) and pork patty (Hur et al., 2008) when used as an animal fat replacer in the products. The grade of olive oil used were extra virgin olive oil(defined by the European Union Commission reg. No. 1513/2001).

2. Fat replacers in processed meat products

Most efforts in developing low-fat meat products to satisfy concerned consumers have been focused on reducing fat and/or substituting animal fats in the formula with plant oils. Fat is an important determinant for the sensory properties of meat and meat products, and thus a simple reduction of animal fat content in the formulation can lead to a product with poor sensory quality. Therefore, strategies to reduce animal fat while retaining traditional flavor and texture of meat products.

Juiciness and mouthfeel are very closely related to the fat content in meat products. To a large extent these sensory quality can be retained by using binders in low-fat and/or healthy meat products. Binders have been added to meat products for many years for both technological reasons and cost savings. Many binders with a number of different properties are available, but all those used in value-added meat products are to improve water binding capacity. Among the binders, carrageenan is the most widely used in meat industry. According to Varnam & Sutherland(1995), iota-carrageenan with calcium ions forms a syneresis-free, clear plastic gel with good resetting properties after shear. It is particularly recommended for use in low-fat products. Iota-carrageenan has very good water retention properties, and enhance cold solubility and freeze-thaw characteristics of processed products. The presence of NaCl in solution inhibits swelling of carrageenan but this difficulty can be solved by using NaCl encapsulated with partially hydrogenated vegetable oil such as olive oil, soya oil, corn oil and palm oil. Hydrogenated corn oils or palm oils are particularly effective in replacing beef fat. Soya oil emulsion is also effective at levels up to 25%, especially when used in conjunction with isolated soya proteins (Varnam & Sutherland, 1995).

Olive oil can be used in processed meat products an an oil-in-water emulsion form (Hoogencamp, 1989). Briefly, water is heated to 60-65°C. This water is homogenized with the isolated soy protein (42.15%, w/w) and the mixture is cooled to 5°C and then placed in a chilled cutter. After homogenizing for 1 min, olive oil is added while homogenization is continued. Finally, the mixture is homogenized for additional 3 min and then used for manufacturing sausages and patties.

The incorporation of olive oil has been studied in fermented sausages (Bloukas et al., 1997; Kayaardi & Gök, 2003; Koutsopoulos et al., 2008) and beef patties (Hur et al, 2008). Partial replacement of animal fats with olive oil has also been tested (ranging between 3–10 g of olive oil per 100 g of product) in frankfurter sausages and low-fat products. Previous studies (Jiménez-Colmenero, 2007; López-López et al., 2009b) indicated that partial replacement of pork backfat with olive oil increased MUFA contents without significantly altering the n-6/n-3 ratio.

3. Incorporation of olive oil in meat products

To develop healthier meat products, various technological options of replacing animal fat have been studied (Jiménez-Colmenero, 2007). Olive oil has been incorporated in meat emulsion systems such as frankfurters in liquid (Lurueña-Martinez et al., 2004; López-López et al., 2009a, 2009b) or interesterified form (Vural et al., 2004). However, oil-in-water emulsion is the most suitable technological option for stabilizing the non-meat fats added to meat derivatives as ingredients due to physicochemical properties (Bishop et al., 1993; Djordjevic et al., 2004). There are a number of procedures that can be used to produce a plant or marine oil-in-water emulsions (with an emulsifier, typically a protein of non-meat origin) for meat products (Jiménez-Colmenero, 2007), but only sodium caseinate has been used to stabilize olive oil for incorporation in frankfurter-type products (Paneras & Bloukas, 1994; Ambrosiadis et al., 1996; Paneras et al., 1998; Pappa et al., 2000; Choi et al., 2009).

Tables 1 and 2 are examples of fmomulas that use olive oil and different fat replacers in producing an emulsion-type sausage and pork patty.

Ingredients (%)		Control	ICM [1)]	ICMO [2)]
Pork ham		68.95	73.24	71.57
Pork backfat		19.25	-	-
Ice/water		9.75	7.71	9.38
Fat replacer	ICM[1)]	-	17.00	12.00
	Olive Oil	-	-	5.00
NPS [3)]		1.30	1.30	1.30
Phosphate		0.20	0.20	0.20
Sugar		0.50	0.50	0.50
Monosodium glutamate		0.05	0.05	0.05
Total		100	100	100

[1)] Isolated soy protein: carrageenan: maltodextrin: water = 2:1:1:20.

[2)] ICM+Olive Oil.

[3)] NaCl: NaNO2 = 99:1.

Table 1. Formulation of emulsion-type low-fat sausages manufactured with and without fat replacers.

	C	T 1	T 2	T 3
Lean pork	83.5	81.0	80.5	80.0
Pork back fat	10.0	5.0	5.0	5.0
Olive oil	-	5.0	5.0	5.0
ISP	-	0.5	0.5	0.5
Carageenan	-	-	0.5	0.5
Maltodextrin	-	-	-	0.5
Salt	1.2	1.2	1.2	1.2
Black pepper	0.3	0.3	0.3	0.3
Water	5.0	7.0	7.0	7.0
Total	100	100	100	100

[1)]C, 10 % backfat; T1, 5 % backfat + 5% olive oil + 0.5 % isolated soy protein; T2, 5% backfat + 5% olive oil + 0.5% isolated soy protein + 0.5% carageenan (T2). T3, 5% backfat + 5% olive oil + 0.5% isolated soy protein + 0.5% carageenan + 0.5% martodextrin.

Table 2. Formulation of pork patty with fat replacers

3.1 Chemical composition and nutritional value of meat products manufactured with olive oil

The chemical composition of emulsion-type sausages indicated that fat content was reduced by replacing the pork backfat with ICM, but increased with added olive oil (Table 3). Replacing backfat with fat replacers resulted in increased fat content at day 30 for ICM and day 15 and 30 for ICMO; however, the control was not differ. These results could be due to increased moisture loss (%) with longer storage time. ICM and ICMO had higher moisture content than control. When pork backfat is fully replaced by oil-in-water emulsion, which contains 52% olive oil, the sausage contains approximately 13 g of olive oil per 100 g of product. This means a considerable increase in the proportion of MUFA. Olive oil can make up almost 70% of the total fat content of the sausage. The caloric content of sausages was 225-245 kcal/100 g, and 70% of which were from fat. In traditional sausages, all are supplied by animal fat, whereas, in the sausage replaced with olive oil, the animal fat supplied only 20%. The other 50% is from the olive oil. It was suggested that meat products, strategically or naturally enriched with healthier fatty acids, can be used to achieve desired biochemical effects without dietary supplements or changing dietary habits (Jiménez-Colmenero et al., 2010).

Up to 7 – 13 g of olive oil could be added per 100 g sausages as an animal fat replacer. However, the purpose of replacing animal fat with olive oil is to produce low-fat products, and consequently such high proportion of olive oil is not desirable (Jiménez-Colmenero et al., 2007). One of the fundamental strategies in developing a healthier lipid formula is concentrating active components in target food products to enable the cosumption of recommended intake levels with normal portion sizes. Dietary models provided by the World Health Organization (2003) suggested that MUFA should be the major dietary fatty acids. If MUFAs are the predominant fatty acids in a product, the total fat intake would not be substantial (Pérez-Jiménez et al., 2007).

Protein content of the sausage (ICMO) containing ICM and olive oil was higher than that of the control. This could be attributed to higher lean content and ISP in the formulation of

ICMO. Therefore, the replacement of animal fat with olive oil may produce products with healthier lipid composition (higher MUFAs, mainly oleic acid) without substantial deterioration in nutritional quality.

In pork patty study, moisture content was significantly higher in the products with olive oil+ISP+carageenan (T2) and T2 with maltodextrin (T3) when compared with control and that with olive oil+ISP (T1) (Table 4). In contrast, control and T1 had significantly higher crude protein than T2 and T3. Crude fat content was higher in T1 and T2. The pork patty with olive oil treatment had higher ash content than control. Pietrasik and Duda (2000) reported that the increased weight losses when the reduction of fat is accompanied by an increase in the proportion of moisture, and protein levels remain essentially the same. However, substitution of backfat with olive oil produced pork patty not only with higher in moisture but also higher fat content than control in this study. Thus, it can be assumed that olive oil substitution for backfat may not induce weight loss of pork patty. These results agreed with Pappa et al. (2000) who reported no significant difference in yield when olive oil was replacing pork fat in low-fat frankfurters.

Treatment	Fat (%)	Protein (%)	Moisture (%)
Control			
1 day	19.72±1.56^{a}	15.06±0.71^{d}	61.96±1.78^{d}
15 days	19.36±1.34^{a}	15.16±0.49^{d}	61.34±1.40^{d}
30 days	19.62±1.44^{a}	15.34±0.70^{d}	61.15±1.46^{d}
ICM[1)]			
1 day	3.34±0.63^{e}	18.38±0.96^{a}	74.58±1.15^{a}
15 days	3.21±0.59^{e}	18.23±0.84^{a}	74.24±1.06^{a}
30 days	4.63±0.46^{d}	17.79±0.52^{ab}	72.77±0.58^{b}
ICM O[1)]			
1 day	7.35±0.19^{c}	16.70±0.75^{bc}	73.24±0.75^{ab}
15 days	8.65±0.29^{b}	17.27±0.50^{ab}	71.08±0.95^{c}
30 days	8.58±0.42^{b}	16.60±0.49^{bc}	71.12±1.06^{c}

[1)] See Table 1.
$^{a-e}$ Means ± S.E. with different letters in the same column indicate significant differences (p<0.05).

Table 3. Chemical composition of emulsion-type low-fat sausages with or without fat replacers

	C	T1	T2	T3
Moisture	60.42±0.65^{B}[2)]	60.32±1.05^{B}	62.15±0.22^{A}	61.63±0.37^{AB}
Crude Protein	23.37±0.44^{A}	20.28±0.62^{BC}	19.54±0.76^{C}	21.30±1.84^{B}
Crude fat	14.93±0.90^{B}	17.34±0.41^{A}	16.29±1.05^{A}	14.88±0.85^{B}
Ash	1.28±0.02^{B}	2.06±0.13^{A}	2.02±0.03^{A}	2.19±0.11^{A}

[1)]See Table 2.
[2)] $^{A-C}$ Means ± SD with different superscripts in the same row significantly differ at p<0.05.

Table 4. Proximate compositions in pork patty made by substituted olive oil for backfat

3.2 Physicochemical properties of meat products manufactured with olive oil

The water holding capacity (WHC) of meat products provide succulent texture and mouthfeel to consumers. A number of studies have proved that there are an inverse relationship between fat content and the amount of water released (Hughes et al., 1997). In Table 5, ICMO was not difference in WHC when compared with the control. It means that olive oil can be combined with other fat replacers such as ISP and carrageenan to improve WHC in meat products. In the case of ICMO, which was emulsified with ISP and carrageenan, the release of water seemed to be protected during storage days.

Cooking loss of meat products is usually influenced by fat content. The products with higher fat content lose less water after cooking ((Jiménez-Colmenero et al., 2007) because high-fat products contain less water. The cook losses of the low-fat sausages manufactured with olive oil and fat replacers (ICM and ICMO) were lower than those of the control (Table 5). However, when the reduction of fat contents in the sausages was considered, the increase of cook loss is not significant. Some fat replacers such as whey protein, carrageenan and tapioca starch could reduce the cook loss of low-fat sausages due to water retainability (Lyons et al., 1999).

Treatment		WHC (%)	Cook loss (%)
Control			
	1 day	71.02 ± 1.17^{a}	13.30 ± 0.37^{cd}
	15 days	69.52 ± 0.89^{ab}	13.18 ± 0.53^{d}
	30 days	68.33 ± 0.93^{b}	13.86 ± 0.52^{bcd}
ICM[1)]			
	1 day	68.32 ± 0.59^{b}	14.37 ± 0.82^{bc}
	15 days	67.95 ± 0.95^{bc}	14.78 ± 0.48^{a}
	30 days	66.77 ± 0.59^{c}	14.90 ± 0.40^{a}
ICMO[1)]			
	1 day	69.79 ± 0.43^{ab}	13.13 ± 0.54^{d}
	15 days	69.12 ± 1.18^{ab}	14.01 ± 0.34^{bc}
	30 days	68.28 ± 0.82^{b}	14.61 ± 0.52^{ab}

[1)] See Table 1., [a-d] Means ± S.E. with different letters in the same column indicate significant differences (p<0.05).

Table 5. Water holding capacity (WHC, %) and cook loss (%) of low-fat sausages with or without fat replacers

	C	T1	T2	T3
pH	5.82 ± 0.03^{A}	5.75 ± 0.02^{B}	5.78 ± 0.01^{B}	5.78 ± 0.02^{B}
WHC (%)	$79.05 \pm 2.22^{A2)}$	72.05 ± 1.12^{B}	80.39 ± 14.58^{B}	83.99 ± 12.65^{A}
Fat retention (%)	79.31 ± 0.02^{C}	83.97 ± 0.01^{B}	84.64 ± 1.06^{B}	86.61 ± 1.28^{A}
Cooking loss (%)	28.05±0.70	27.30±0.69	27.72±1.10	26.95±1.61

[1)] See Table 2., [2)] [A-C] Means ± SD with different superscripts in the same row significantly differ at p<0.05.

Table 6. Changes of physical characteristics in pork patty made by substituted olive oil for backfat

On other hand, WHC of pork patty was significantly higher in control and T3 than T1 and T2. Control had higher pH than olive oil-added pork patties, but no significant differences were found among the samples with 50% olive oil substitution for backfat. Fat retention was higher in the olive oil-substuted samples than control. Especially T3, the patty with olive oil+ISP+carageenan, showed the highest fat retention. However, cooking loss was not different among the treatments. In this present study, WHC was steadily decreased as olive oil substitution level increased. However, this does not mean that the quality of pork patty decreased, because fat retention was higher in olive oil-added pork patties, and cooking loss was not significantly different.

In other meat product studies, Kayaardi and Gok (2003) reported that replacing beef fat with olive oil had no effect on the pH value of the Soudjouks samples. Luruena-Martinez et al. (2004) and Muguerza et al. (2002) reported that the addition of olive oil did not produce significant differences in cooking losses of sausage but made the sausage lighter in color and more yellow (Muguerza et al., 2002). In contrast, Bloukas et al. (1997) reported that the higher the olive oil content, the higher the weight loss, probably due to higher amounts of water added. Hur et al. (2008) repoprted that WHC was decreased but fat retention was increased by olive oil substitution.

3.3 Color and lipid oxidation of meat products manufactured with olive oil

Color of meat products is an important quality parameter for purchase decision by consumers. The most common cause for changing color is the formation of metmyoglobin by oxygen-dependent meat enzymes. Aerobic micro-organisms are successfully competing with meat pigments for oxygen. Formation of metmyoglobin can vary, and occasionally discolored areas are present adjacent to and fully demarcated areas where coloration is bright pink. Use of low-quality fat containing high levels of peroxides can cause oxidation of meat pigments (Varnam & Sutherland, 1995).

Varnam & Sutherland(1995) reported that sausages can have a number of specific quality issues: 'Pressure marks' are the result of oxygen deficiency where packed sausages are in close contact to each other. Pigment is initially converted to reduced myoglobin and subsequently, as some diffusion of oxygen occurs, to metmyoglobin. 'White spot' appears to be an oxidative defect, which involves formation of circular grey or white areas that increase in size with continuing storage. It could be associated with low SO_2 levels and use of fats with a high peroxide content.

The sausage incorporated with ICM and olive oil as fat replacers showed higher yellowness and redness (Table 7). Yellower color could be from the original color of olive oil and redder color from higher lean ratio, which includes higher myoglobin content, compared to traditional sausages (control).

Olive oil and ISP are known to have antioxidant properties. The sausages emulsified with ISP and olive oil (ICMO) inhibited lipid oxidation (Table 7). The progress of lipid oxidation can cause changes of meat quality including color, flavor, odor, texture and even the nutritional value in meat products (Fernandez et al., 1997). The stability of fat often limits the shelf life of meat products. The incorporation of olive oil and ISP into meat products may improve the shelf life of the products due to their antioxidant properties. In our study, TBARS values of ICMO were lower than those of the control on days 15 and 30. The TBARS of ICMO sample remained constant throughout the 30 days of storagebut those of the control and ICM increased ($p< 0.05$) from days 15 to 30. The higher TBARS value for the control on each storage day might be due to high fat content in control sausages.

Treatment	Lightness (L^*)	Redness (a^*)	Yellowness (b^*)	TBARS (mg malonaldehyde/kg sample)
Control				
1 day	78.39±0.37^{a}	11.06±0.21^{b}	3.45±0.17^{b}	0.16±0.03^{c}
15 day	77.25±0.64^{ab}	10.41±0.19^{b}	2.34±0.24^{c}	0.22±0.03^{b}
30 day	76.41±0.88^{b}	10.22±0.09^{b}	2.49±0.61^{bc}	0.32±0.05^{a}
ICM[1)]				
1 day	74.95±0.69^{c}	12.13±0.40^{a}	3.30±0.16^{b}	0.16±0.02^{c}
15 day	73.48±0.98^{cde}	10.42±0.07^{b}	2.42±0.24^{bc}	0.14±0.04^{cd}
30 day	71.69±1.31^{e}	10.29±0.13^{b}	2.20±0.05^{c}	0.24±0.02^{b}
ICMO[1)]				
1 day	73.45±0.18^{de}	11.80±0.64^{ab}	4.04±0.13^{a}	0.17±0.02^{c}
15 day	72.49±0.17^{e}	10.46±0.25^{b}	2.44±0.15^{bc}	0.15±0.04^{cd}
30 day	72.01±0.65^{e}	10.31±0.06^{b}	2.79±0.13^{bc}	0.20±0.03^{bc}

[1)] See Table 1., $^{a-e}$ Means ± S.E. with different letters in the same column indicate significant differences (p<0.05).

Table 7. Color and lipid oxidation of low-fat sausages with or without fat replacers

L*-value of raw pork patty was higher in control and T1 than other samples, but no significant difference were found after cooking (Table 8). a*-value was significantly higher in control than the samples with olive oil-added products in both raw and cooked states. It can be assumed that redness may be higher in control than olive oil-added pork patties, but lightness and yellowness may not be much different. Paneras et al. (1998) also reported differences in color when low fat frankfurters were produced with different levels of vegetable oils. Low-fat frankfurters were darker, redder and more yellow than high fat frankfurters. However, Marquez et al. (1989) found no differences in color parameters by oil treatments in beef frankfurters. These studies indicated that the change of meat color by oil treatment can vary depending upon the meat products.

	Color	C	T1	T2	T3
Raw sample	L*	55.89±1.46^{A}[2)]	55.31±0.96^{A}	52.00±0.62^{B}	52.58±1.32^{B}
	a*	13.86±0.35^{A}	11.75±0.63^{B}	11.75±0.45^{B}	11.84±0.52^{B}
	b*	9.46±0.09	9.77±0.48	9.04±0.70	9.48±0.49
Cooked sample	L*	62.11±5.90	63.98±3.58	66.71±0.40	66.26±1.94
	a*	7.60±0.30^{A}	7.02±0.33^{B}	6.67±0.13^{BC}	6.07±0.24^{C}
	b*	9.37±0.73^{B}	11.06±0.08^{A}	8.57±0.56^{C}	9.80±0.93^{AB}

[1)] See Table 2.,

[2)] $^{A-C}$ Means ± SD with different superscripts in the same row significantly differ at p<0.05.

Table 8. Changes of meat color in pork patty by substituting backfat with olive oil

Chin et al. (1999) and Claus et al. (1990) found that redness and lightness values were more affected by fat/lean ratio and myoglobin concentration of the lean part. Muguerzaet al. (2002) and Bloukas et al. (1997) also found that replacing, in part, backfat with olive oil produced yellower sausages than controls. Muguerza et al. (2002) reported that antioxidant present in olive oil and ISP helped maintaining color by minimizing color oxidation. The present study is in agreement with the findings of other researchers (Kayaardi & Gök, 2003; Ansorena & Astiasarán, 2004; Bloukas et al., 1997) who reported increase of lipid oxidation in meat products during fermentation and ripening period. They found that replacing animal fat with olive oil was effective for inhibiting the lipid oxidation during storage. Our previous and present results indicated that replacing animal fat with olive oil can be effective in inhibiting lipid oxidation in meat products during storage.

3.4 Texture and sensory properties of meat products manufactured with olive oil

Textural properties of the emulsion-type sausages are affected by the replacement of backfat with olive oil emulsion (Table 9). In general, frankfurters made with oil-in-water emulsions presented higher hardness, cohesiveness and chewiness and lower adhesiveness than traditional frankfurters. The textural properties of frankfurters manufactured with olive oil are influenced by the characteristics of oil-in-water emulsion and its role in the meat protein matrix. Frankfurters with olive oil emulsion containing caseinate or soy protein presented similar hardness and chewiness to control, but those with soy protein presents higher springiness and cohesiveness (Jiménez-Colmenero et al. 2010) (Table 9).

The frankfurters containing olive oil emulsion with caseinate or soy protein had higher hardness, cohesiveness, gumminess and chewiness values than the traditional sausages. The result of texture might be due to the reduced fat content sausages. In high fat frankfurters, in which pork backfat is replaced by olive oil, generally have less flavor intensity and are harder and less juicy (Jiménez-Colmenero et al., 2010). However, these differences are marginal, and the frankfurters received similar scores for general appearance and acceptability (Jiménez-Colmenero et al., 2010). Partial substitution of animal fat with olive oil reduced juiciness scores.

Parameter	Control	ICM[1)]	ICMO[1)]
Hardness (kg)	0.33±0.04b	0.42±0.02a	0.40±0.03a
Cohesiveness	60.85±1.52[b]	66.47±0.90[a]	66.09±0.54[a]
Springiness	13.11±0.27	13.53±0.04	13.23±0.24
Gumminess (g)	19.26±0.88[b]	22.09±0.65[a]	21.74±0.30[a]
Chewiness (g)	228.70±6.02[b]	271.28±6.30[a]	268.11±8.55[a]

[1)] See Table 1.
[a-b] Means ± S.E. with different letters in the same row indicate significant differences (p<0.05).¶(9pt)

Table 9. Textural attributes of low-fat sausages with or without fat replacers

The textural properties of pork patties are presented in Table 10. Brittleness and hardness were significantly higher in the patties with olive oil than control, whereas springiness was the lowest in T1. Cohesiveness, gumminess and chewiness were significantly higher in T2 and T3 than control and T1. Chin et al. (1999) found higher hardness values when animal fat was replaced with a mixture of ISP and carrageenan in 30% fat bologna sausages. These results are similar to the findings of Crehan et al. (2000), who reported that added maltodextrin treatment as a fat replacer had higher hardness, gumminess and chewiness than control in 12% fat sausages. The present study was also supported by the findings of Pietrasik and Duda (2000) who reported that replacing backfat with the mixture of carrageenan and ISP was positively correlated with hardness, cohesiveness, gumminess and chewiness. Bloukas et al. (1997) found that fermented sausages with direct incorporation of olive oil in liquid form were softer than control sausages. Luruena-Martinez et al. (2004) also reported that olive oil addition together with fat reduction caused a significant decrease in hardness and the related parameters such as chewiness and gumminess due to high monounsaturated fat in the product. In contrast, we found that pork patties made with olive oil were not only harder but also higher in other mastication power compared with control. Usually, a decrease in textural properties with the increase in olive oil are expected because a solid fat is replaced with a liquid oil. (, the changes of mechanical texture should be influenced by other ingredients such as a carageenan and maltodextrin used in this study.

	C	T1	T2	T3
Brittleness (g)	0.42±0.11$^{B2)}$	0.72±0.17^{A}	0.72±0.03^{A}	0.60±0.17^{AB}
Hardness (g)	470±40.0^{B}	720±16.0^{A}	730±40.0^{A}	600±17.0^{A}
Cohesiveness (%)	49.44±6.49^{AB}	37.53±10.17^{B}	52.04±1.74^{A}	54.09±6.34^{A}
Springiness (%)	13.64±0.08^{A}	11.83±1.67^{B}	13.66±0.31^{A}	13.69±0.15^{A}
Gumminess (g)	23.08±2.09^{B}	27.58±12.44^{AB}	37.84±2.74^{A}	31.75±5.72^{AB}
Chewiness (g)	314.87±27.14^{B}	312.43±90.27^{B}	517.31±47.06^{A}	434.42±75.27^{A}

1) See Table 2.
2) A-B Means ± SD with different superscripts in the same row significantly differ at $p<0.05$.

Table 10. Changes in the textural properties of pork patties by substituting backfat with olive

In sensory evaluation, ICMO was rated the lowest for color and overall acceptability when compared with the control, traditional sausages (Table 9). Muguerza et al. (2002) reported that sausages, which replaced 30 or 20% backfat with 20% olive oil, were rated worse for color, odor and taste than without added olive oil. However, panels did not recognize the differences in flavor and juiciness between ICMO and traditional sausages in the present study. Bloukas and Paneras (1993) found that low-fat frankfurters (11% fat content) with olive oil had similar flavor but were less palatable than the traditional frankfurters (28% fat content). Lyons et al. (1999) also found that the combination of whey protein concentrate, carrageenan and starch resulted in a low-fat sausage with similar mechanical and sensory characteristics to 20% full-fat sausages. High fat sausages (26%) are less firm and juicy than low-fat sausages (10%) made with a combination of olive, cottonseed and soybean oils but it is difficult to realize the differences in overall acceptability (Jiménez-Colmenero et al., 2010).

Sensory attributes	Control	ICM[1)]	ICMO[1)]
Color	6.10±0.88^{a}	6.50±0.97^{a}	4.60±0.70^{b}
Aroma	5.60±0.70	5.90±0.48	5.50±0.53
Flavor	5.90±0.88	6.10±0.74	5.50±1.08
Tenderness	5.36±0.42^{b}	6.10±0.37^{a}	5.87±0.64^{ab}
Juiciness	5.90±0.74	6.00±0.94	6.00±1.05
Overall acceptability	6.10±0.74^{ab}	6.25±0.79^{a}	5.50±0.85^{b}

[1)] See Table 1.
[a-b] Means ± S.E. with different letters in the same row indicate significant differences (p<0.05).

Table 11. Sensory attributes of low-fat sausages with or without fat replacers

The sensory evaluation of pork patties (Table 12) indicated that color, aroma and flavor of control were higher than those of the olive oil-added ones, whereas tenderness was higher in olive oil-added samples.

	C	T1	T2	T3
Color	6.90±0.32^{A}	6.40±0.52^{AB}	6.30±0.67^{B}	6.50±0.53^{AB}
Aroma	6.90±0.88^{A}	5.70±0.48^{B}	5.70±0.48^{B}	5.40±0.52^{B}
Flavor	6.40±0.52^{A}	5.60±0.70^{B}	5.60±0.52^{B}	5.60±0.70^{B}
Tenderness	5.20±0.42^{B}	5.70±0.67^{AB}	5.50±0.53^{AB}	5.90±0.74^{A}
Juiciness	5.00±0.82	4.70±0.67	4.80±0.63	4.90±0.74
Overall acceptability	7.20±0.42^{A}	6.40±0.84^{B}	6.50±0.71^{B}	6.80±0.63^{AB}

[1)] See Table 2.,
[2)] [A-B] Means ± SD with different superscripts in the same row significantly differ at p<0.05.

Table 12. Changes of sensory evaluation value in pork patty made by substituted olive oil for backfat

Control was significantly higher in overall acceptability than olive oil-added pork patties. The substitution of pork backfat with olive oil is limited as it may affect the taste of the pork patty. Pappa et al. (2000) reported that the replacing pork backfat with olive oil positively affected the overall acceptability of the low-fat frankfurters. In contrast, Bloukas and Paneras (1993) reported that low-fat frankfurters produced by total replacement of pork backfat with olive oil had lower overall palatability than high-fat frankfurters produced with pork backfat. The ingredients used or the amount of olive oil added in the formula could have influenced this difference in sensory scores. Also, the effect of olive oil substitution of backfat on quality can vary depending upon meat products. The patties with olive oil had lower sensory evaluation scores. Meanwhile, tenderness was higher in the sample with olive oil than the control. Paneras et al. (1998) reported that low-fat frankfurters produced with vegetable oils were firmer and less juicy than high-fat controls. A possibility of reducing the negative effects due to the high fat content of these products is partially substituting pork backfat with other ingredients (Muguerza et al., 2001). Fat is very important for the rheological and structural properties of meat products and the formation of a stable emulsion (Luruena-Martinez et al., 2004). The tenderness of olive oil-added pork patties were higher than control because olive oil is more fluid than backfat in sensory evaluation.

4. Conclusion

The addition of olive oil to a mixture of fat replacer resulted in somewhat undesirable color and overall acceptability, but lipid oxidation was inhibited. Soem quality problems including color of sausages can be minimized by combining carrageenan, maltodextrin and isolated soy protein with olive oil. The physical properties of pork patties made with olive oil emulsions were stable when compared with commercial pork patties, but they were significantly influenced by other ingredients in the oil emulsions. In conclusion, the use of olive oil in meat products to replace backfat may have a beneficial effect to human health. However, sensory quality of the products needs further improvment so that the product is compatible to conventional products

5. Acknowledgment

This work was supported by Priority Research Centers Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2009–0093813).

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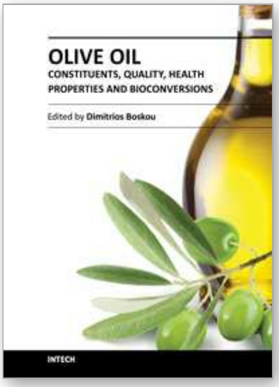

Olive Oil - Constituents, Quality, Health Properties and Bioconversions

Edited by Dr. Dimitrios Boskou

ISBN 978-953-307-921-9
Hard cover, 510 pages
Publisher InTech
Published online 01, February, 2012
Published in print edition February, 2012

The health-promoting effects attributed to olive oil, and the development of the olive oil industry have intensified the quest for new information, stimulating wide areas of research. This book is a source of recently accumulated information. It covers a broad range of topics from chemistry, technology, and quality assessment, to bioavailability and function of important molecules, recovery of bioactive compounds, preparation of olive oil-based functional products, and identification of novel pharmacological targets for the prevention and treatment of certain diseases.